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THE UNIVERSITY OF ALBERTA

A COMPARISON OF JOGGING PROGRAMS

by



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A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF MASTER OF SCIENCE

DEPARTMENT OF PHYSICAL EDUCATION

EDMONTON, ALBERTA

SPRING, 1971

thesis
1971
169

UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "A Comparison of Jogging Programs" submitted by Paul Webster in partial fulfilment of the requirements for the degree of Master of Science.

ABSTRACT

The purpose of the present investigation was to assess changes in cardiorespiratory endurance after a six-week jogging program. In addition, the study included a comparison of improvement in aerobic power by individuals within the same treatment who exhibited varying degrees of fitness at the initiation of the jogging program. Finally, Pearson Product-moment correlation coefficients were obtained between the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the initiation and completion of the jogging program.

Eighty high school students were divided into four treatments. Group I jogged $3/8$ of a mile, Group II, $3/4$ of a mile, and Group III, 1 mile. Group IV acted as a control. Jogging was carried out daily for six weeks on an indoor track. While the duration of jogging varied, intensity was held constant. That is, lap times were identical for each of the three groups each week. The intensity increased weekly during the six weeks of jogging.

Changes in aerobic power at the completion of the jogging program were determined by again employing the twelve-minute run-walk and the Astrand-Ryhming nomogram test.

Results indicated that all three experimental groups exhibited a significant increase in both the twelve-

minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ over the six-week jogging program. No significant change in either variable was found to occur in the control group. Significant differences in the twelve-minute run-walk were found to occur between treatment II (3/4 mile) and treatment IV (control) and treatment III (1 mile) and treatment IV at the completion of jogging. On the other hand, no significant differences in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ were found between treatments at the conclusion of jogging. Furthermore, no significant differences in improvement in aerobic power (twelve-minute run-walk, predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$) were found when the upper and lower halves of each treatment were compared. Finally, correlations of 0.59 and 0.56 were found between the distance covered in twelve minutes and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the initiation and completion of the jogging program respectively.

Within the limitations of the study, it was concluded that:

1. While all three experimental groups improved significantly in both the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the completion of six weeks of jogging, no significant differences in improvement in either variable were found between experimental treatments. A significant difference was found to occur only between Treatment II and Treatment IV and Treatment III and Treatment IV in the twelve-minute run-walk.

2. Mean improvement in cardiorespiratory fitness

(twelve-minute run-walk, predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$) over six weeks of jogging was not found to be significantly different when the upper and lower halves of each treatment were compared.

3. Significant correlations of 0.59 and 0.56 were found to exist between the distance covered in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the initiation and completion of the six-week jogging program respectively.

ACKNOWLEDGEMENT

Sincere thanks and gratitude is extended to Dr. M. Singh, the thesis chairman, and to Miss Patricia Conger and Dr. T. Maguire for their assistance, guidance and encouragement.

A special acknowledgement is extended to Mr. Don Vosburgh who gave his time and assistance unselfishly throughout the study.

Finally, to the eighty subjects who endured the six weeks of jogging, your participation was sincerely appreciated. Thank-you.

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CHAPTER I

STATEMENT OF THE PROBLEM

INTRODUCTION

As a primary objective of physical education, the attainment of physiological fitness has overwhelming implications in the growth and development of both youth and adults alike. Yet the term 'physical fitness' is poorly defined and often connotes a number of divergent and sometimes opposing views. The controversial problem of defining physical fitness has evolved from both disagreement on those elements constituting fitness and on what measures effect valid indices of comparison. (41) Consequently, the term cardiorespiratory fitness, a specific parameter of physical fitness will be employed. Cardiorespiratory fitness may be defined as:

The ability to maintain the processes of metabolic exchange as close to the resting potential as is mutually possible during the performance of a strenuous and fully learnt task for a moderate time, with the capacity to reach a higher rate of working than the unfit and to restore promptly all equilibria which are disturbed. (61:112)

Regardless of such innate characteristics of sex, age or somatotype, training produces modifications in an individual's work capacity. Increased physiological efficiency through training results in the ability to prolong homeostasis or to reduce displacement from resting

equilibria in response to an equal amount of work. Maximal inter-individual physiological efficiency on the other hand has a considerable range of values. As a result, outstanding athletic performance is obtainable by only a comparatively small number of individuals who possess an optimal degree of physiological functioning. (13)

In exhaustive exercise, the intensity and duration of the activity are circumscribed by the limits of the physiological functions involved. Because prolonged heavy work may ultimately depend upon the ability of the organism to deliver oxygen to the working muscles, and because the rate of oxygen transport is dependent upon the pulmonary and cardiovascular systems, maximal oxygen consumption at present gives the best available estimate of cardiorespiratory fitness. (46)

It has been confirmed empirically as well as experimentally that exercise of increasing intensity repeatedly carried out leads to improved performance. The physiological principle upon which this is dependent is that of overload. In jogging, this amounts to covering a greater distance in the same time or covering the same distance more quickly or with less fatigue. As soon as improvement in performance can be demonstrated, the process of training may be said to have begun.

Re-evaluation by Cooper of Balke's 15-minute field test to estimate maximal oxygen consumption has lead to the incorporation of a 12-minute maximal distance field test.

One hundred and fifteen United States Air Force male officers and airmen were evaluated on a treadmill maximal oxygen consumption test as well as a number of field performance tests. It was found that the maximal distance covered in twelve minutes correlated best with MVO_2 established on the treadmill ($r=0.897$) when compared to similar field tests with times varying from 6-20 minutes. The distance covered in twelve minutes may roughly be converted into mls. O_2 consumed/kgm./min. Because the test is considered to be a maximal performance test, this figure represents maximal oxygen consumption.

The significance of the above relationship makes it possible to estimate MVO_2 with considerable accuracy from the results of the twelve minute performance test.

Because of the high correlation with MVO_2 , it can be assumed that the twelve-minute field performance test is an objective measure of physical fitness reflecting the cardiovascular status of an individual.
(15:201)

A second criteria that may be employed in the assessment of an individual's aerobic capacity is the Astrand-Ryhming nomogram. Unlike the twelve-minute maximal distance field test, the Astrand-Ryhming nomogram is a submaximal, 'laboratory' test. By knowing both the work level or the oxygen consumption at submaximal levels as well as the steady state heart rate concurrent with that load or oxygen intake, maximal oxygen consumption may be predicted.

The question is often asked: How long and at what

intensity must one participate in vigorous activity in order to elicit a significant improvement in aerobic power? It is hypothesized that cardiovascular adaptations may be related to the duration of jogging when both the intensity and frequency of training sessions are held constant.

THE PROBLEM

By employing the twelve-minute run-walk and the Astrand-Ryhming nomogram as tests of cardiorespiratory endurance, it is the purpose of the present investigation to determine changes in aerobic fitness as a result of three jogging programs of similar intensity and frequency but varying duration. In addition, the relationship between improvement in cardiorespiratory endurance and initial fitness levels within each training program will be investigated. Finally, Pearson Product-moment correlation coefficients between the twelve-minute run-walk and predicted MVO_2 at the initiation and completion of jogging are to be determined.

The following hypotheses will be tested:

1. No significant improvement in aerobic power takes place within each treatment as a result of the jogging regime.
2. No significant differences in cardiorespiratory endurance occur between Treatments at the completion of the jogging program.

3. No significant differences in improvement in aerobic power occur between the upper and lower halves of each Treatment with training.

4. An insignificant correlation exists between the distance covered in the twelve-minute run-walk and maximal oxygen consumption predicted by the Astrand-Ryhming nomogram.

JUSTIFICATION OF THE STUDY

It is assumed that through this investigation, one will be able to answer more assuredly questions involving intensity and duration of training and the resultant effect on cardiorespiratory fitness. Secondly, by determining the relationship between the maximal distance covered in twelve minutes and maximal oxygen uptake predicted by the Astrand-Ryhming nomogram, the application of the twelve-minute run-walk as a test of aerobic power may be further validated.

LIMITATIONS

Part of the difficulty encountered in objectively assessing changes in aerobic power is the result of the failure of any one test to adequately predict changes due to training. Limitations are therefore imposed upon the study by the reliability, validity and underlying assumptions of the twelve-minute run-walk and the Astrand-Ryhming nomogram. Limitations are also imposed as a result of lack

of previous research on which to base the training programs.

DELIMITATIONS

Optimal intensity and duration levels of jogging necessary to elicit changes in cardiorespiratory fitness are difficult to establish since they depend upon the particular level of fitness desired as well as the initial level of fitness of the subjects involved. The subjects who participated in the present investigation were high school students enrolled in the compulsory physical education program.

DEFINITION OF TERMS

Cardiorespiratory Endurance or Fitness

The ability to maintain the processes of metabolic exchange as close to the resting potential as is mutually possible during performance of a strenuous and fully learnt task for a moderate time, with the capacity to reach a higher rate of working than the unfit and to restore promptly all equilibria which are disturbed. (61:112)

Maximal Oxygen Uptake, Intake or Consumption (MVO_2)

The maximum amount of oxygen an individual utilizes in strenuous activity relative to the activity performed.

Aerobic Power

The term is used synonymously with maximal oxygen uptake.

Training

A regular regime of exercise that is carried out over a period of time and that encompasses the principle of overload.

Training Stimulus

The response to training that results in an increased capacity to maintain the processes of metabolic exchange closer to those of the resting potential during strenuous activity.

Inter-Individual Variance

That variance attributable to true differences between individuals.

Intra-Individual Variance

That variance attributable to fluctuations in the physiological functioning of an individual.

CHAPTER II

REVIEW OF THE LITERATURE

During prolonged heavy exercise, an individual's performance capacity is influenced by several factors. In general, performance is dependent upon the following: energy output (both aerobic and anaerobic processes) neuro-muscular functioning and psychological variables. (4)

Maximal cardiorespiratory endurance may depend largely on the ability to deliver oxygen to the working muscles. A measurement of MVO_2 gives the maximal rate of energy output by combustion within the body. Hence, MVO_2 appears to offer the possibility of determining one of the limiting factors in endurance performance characterized by a high level of energy expenditure. (65) Various authors consider MVO_2 or aerobic capacity to be the best measure of cardiorespiratory fitness. (4, 45, 65, 66) If it is assumed that cardiac output increases linearly with the rate of oxygen uptake, MVO_2 also indicates the functional level of the circulatory system. (4) Consequently, MVO_2 is probably the best measure of physical fitness providing the definition of fitness is restricted to the capacity of an individual for prolonged physical exertion. Thus it is primarily cardiorespiratory fitness that is taken as a measure of physical fitness. (35)

In an analysis of the factors influencing oxygen transportation during muscular work, the following may be identified: pulmonary ventilation, oxygen diffusing capacity across the lungs, cardiac output, rate of blood flow through the muscles, capillary oxygen diffusing capacity and finally, the oxygen transporting capacity of the blood. (2)

The findings of Grollman (32) support the concept that an important determinant of cardiac output, and consequently MVO_2 , is the muscle mass employed in performing an activity, for MVO_2 is only maximal for a specific task. Only one activity, skiing with poles, has been shown to elicit a higher MVO_2 than running. (2) Secondly, because MVO_2 is dependent upon the muscle mass being used, it would appear that MVO_2 is independent of skill as long as changes in skill do not produce any changes in muscle mass. Skill however may determine the rate at which MVO_2 is reached. (2)

EFFECTS OF TRAINING ON AEROBIC AND ANAEROBIC CAPACITIES

Several studies have described various differences between the trained and untrained state. It immediately becomes necessary to separate the more useful and less common 'longitudinal' studies' in which the effects of training are studied over a period of time on the same individual, and studies that contrast trained and untrained

subjects at one particular period of time. (65)

It has been clearly shown that physical training affects MVO_2 (47, 55) and the level of oxygen consumption at which anaerobic metabolism is initiated. (74) Robinson and Harmon (55) tested nine previously untrained men before and after 28 weeks of hard physical training and found an elevation in MVO_2 of 14 percent. Knehr et al. (47) followed a group of sixteen men during a training regime of six months and found an average increase in MVO_2 of 7 percent. Ekblom et al. (27) investigated the effects of sixteen weeks of training (three times weekly, cross-country running) by eight males on submaximal and maximal work performed on a bicycle ergometer. The group mean MVO_2 increased 16.2 percent (3.13-3.68 l./m.), partly due to an increased A-VO_2 difference (138-143 mls./l.) and partly due to an increased cardiac output (22.4-24.2 l./min.). Since maximal heart rate was unchanged, the main cause for the increased cardiac output was a stroke volume increase (112-127 mls.).

The above results however failed to show how MVO_2 and anaerobic capacities change in relation to one another within the same individual as a result of training. It was uncertain therefore whether the increased capacity for exercise in the trained individual was due to an increase in MVO_2 or whether it was due to a rising of the level of oxygen intake relative to the individual's maximum at which anaerobic metabolism commenced.

Williams et al. (68) have determined changes in both MVO_2 and the level of oxygen intake at which anaerobic metabolism begins in individuals before and after a regime of bicycle ergometer training at intensities at both aerobic and anaerobic levels. Results indicated that training produced increases in both MVO_2 and the level of oxygen intake at which 'excess lactate' appeared in the blood. The increased MVO_2 ranged from 1-20 percent (average 7 percent) while the level of oxygen uptake relative to the maximum at which excess lactate appeared rose 4-33 percent (average, 16 percent). In the untrained condition, anaerobic metabolism commenced at an average of 46 percent MVO_2 while after training it increased to 62 percent. These results indicate the two parameters may change independently of each other - the percentage increase in the level at which anaerobic metabolism occurred was greater than the percentage increase in MVO_2 following the training period.

Although the mechanisms involved in the training process are not clearly understood, these results suggest that the oxygen demand of the working muscles remains in equilibria with oxygen consumption at higher levels of work in the trained individual than in the untrained. It appears then that the training process produces an increase in oxygen availability to the working muscles (increased cardiac output, blood haemoglobin or A-VO_2 differences) and/or an increase in muscular efficiency (less oxygen consumed per unit of work).

EFFECTS OF TRAINING ON OTHER PHYSIOLOGICAL PARAMETERS

The value of physical activity as a means of eliciting beneficial changes in the physiological functioning of the human organism is fully established in the literature. It is also evident that these changes may be induced by a jogging program of sufficient intensity and duration.

Under the supervision of a university track coach and a physician, three 12-week jogging programs were conducted by Harris et al. (33). Of the 363 men (age range, 30-66 years) who started the program, 265 completed the 12-week schedule.

Results indicated that prior to the jogging, 212 of those completing the program were overweight by an average of 17.5 pounds (based on life insurance statistics). As a result of the jogging, overweight participants lost an average of 7.8 pounds with no emphasis on dieting.

Among the 265 men completing the program, there was an average decrease in circumference of the waist of 1.4 inches. Blood pressure readings at rest showed an average drop in systolic pressure of 11.4 mm. Hg. and in diastolic pressure of 7.8 mm. Hg. There were no significant changes in vital capacity or maximum expiratory flow rates.

In a similar study, Steadward and Singh (63) have examined the extent to which P.W.C.₁₇₀ and other related

variables in sedentary males may be modified by an exercise program consisting entirely of jogging. Eighty male subjects were divided into four groups according to ten-year increments in age; 20-29, 30-39, 40-49 and 50-plus. Training intensity was measured as a 'coefficient of intensity of exercise' (Q) and was computed from the following formula:

$$Q = \frac{\text{miles/session} \times \text{number of sessions per week}}{\text{time for one mile}}$$

Results indicated that improvement in 'Q' ranged from 82.83 percent in the 20-29 year olds to 41.26 percent in the 50-plus year olds over three months of training. Systolic and diastolic pressure decreased 2.95 mm. and 5.12 mm. Hg. respectively. There was a 4.41 percent increase in average vital capacity while resting heart rate decreased 8.68 percent.

The above two studies agree with numerous others (17, 26, 27, 46, 47, 55) on the effects of training and no challenge is offered to contravene these effects. Rather it is a question of intensity and duration of training--that is, what critical level must training exceed in order that significant physiological changes related to cardio-respiratory fitness will take place, and, what is the optimal amount of training required to elicit these changes.

SELECTION OF A TRAINING STIMULUS

Although the principle of overload has been well

established, the exact nature of the training stimulus is unknown. In order to delimit the threshold intensity of effort at which a training stimulus occurs, Karvonen et al. (46) trained six sedentary subjects on a treadmill at a predetermined heart rate for thirty minutes, 4-5 times weekly for four weeks. Results of the investigation indicated that in order for a training effect to occur (constant heart rate at increasing treadmill speed), the critical intensity of effort, expressed as a percentage of the training pulse from rest to maximal rate attainable, appeared to be approximately 60 percent.

De Vries has expressed Karvonen's theory as a formula. For a subject with a resting pulse rate of 70 beats per minute (bpm) and a maximum of 200 bpm., the theoretical critical level of intensity required to effect a training stimulus would be $70 + .60 (200-70) = 148$ bpm.

Further evidence supporting Karvonen's investigation may be found in the literature. Mulloy (51) has found that for a sample of university students, the critical heart rate needed to significantly improve aerobic capacity was about 140 bpm. Holman and Venrath (37) have demonstrated that increases in aerobic capacity were negligible with a heart rate during training of less than 130 bpm.

On the other hand, the concept that a threshold intensity of effort corresponding to a pulse rate of 140-150 bpm. is necessary for a cardiorespiratory training effect to occur has not been substantiated in all

investigations (26) and may depend in part upon the initial fitness level of the subjects involved. Shephard (60) believes that the threshold suggested by Karvonen may be substantially lower in sedentary subjects since they do not normally experience pulse rates greater than 120 bpm.

EFFECTS OF INTENSITY AND DURATION OF JOGGING
ON CHANGES IN CARDIORESPIRATORY ENDURANCE

Durnin et al. (26) have investigated the effects of varying degrees of walking conducted over short periods on improvement in cardiorespiratory fitness. Forty-four untrained army personnel with a mean age of 22 years were divided into four groups: group I walked 10 km./day, group II, 20 km./day, group III, 30 km./day, while group IV acted as the control. Training consisted of two consecutive five-day periods with an intervening one-day admission. Each subject was tested on a treadmill (5.6km./hr., 10 percent grade) for 15 minutes before, during and after the training regime. Following the first 5 minutes of testing, heart rate, oxygen consumption and pulmonary ventilation were measured continuously. Heart rate was also monitored during the initial 10 minutes of recovery.

Results indicated that only the 20 km./day group showed a significant decrease in pulmonary ventilation and oxygen consumption determined on the treadmill. Heart rate showed a significant decrease in all three groups. Recovery heart rates on the other hand showed poor uniformity.

In a comprehensive medical and physiological evaluation, Wilmore (69) has investigated the effects of an eleven-week jogging program on 55 participants with ages ranging from 17-66 years. The 55 subjects were divided into subgroups by ten-year increments in age and each subgroup was in turn divided once again. One group was assigned a jogging program of twelve minutes per day, 3 days per week, while the other was assigned to a routine of 24 minutes, 3 days per week..

In the entire sample a 1-2 percent reduction in body weight was found along with an 8 percent decrease in body fat. There was a significant increase in vital capacity and a decrease in residual lung volume. Resting systolic and diastolic blood pressures dropped 10-13 percent and resting heart rate dropped 12 percent. MVO_2 was found to increase 7-10 percent.

Finally, results showed a notable similarity in changes in both exercise groups. Changes shown by subjects jogging 24 minutes were not significantly greater than those subjects jogging 12 minutes. With a longer training period however, the 24-minute group might have shown statistically greater changes. On the other hand, the pace of the activity may be an important factor in determining the extent of physiological change.

PHYSICAL WORK CAPACITY AND
MAXIMAL OXYGEN UPTAKE

Astrand (4:316) states:

For maintaining a normal equilibrium in the different tissues under varying conditions an adequate blood supply will always be the most important prerequisite. The type of fitness that is necessary for prolonged muscular exercise is well correlated to the individual's oxygen uptake capacity.

Astrand (4) has further commented that aerobic capacity or MVO_2 , when divided by body weight, is probably the best measure of cardiorespiratory endurance. Rodahl (56:500) supports this comment by referring to MVO_2 as ". . . the best indication of physical work capacity . . .," that is, ". . . the individual's total ability to perform prolonged physical work." Because MVO_2 gives the maximal rate of energy output by combustion within the body, MVO_2 may be a limiting factor in endurance performance characterized by a high level of energy expenditure.

If MVO_2 is related to work capacity as the literature suggests, one would expect at least a moderate correlation between it and some actual work task.

Taylor (64) used a time run on a treadmill and found that in submaximal exercise, oxygen consumption was chiefly a function of body weight ($r=0.71$) and was unrelated to endurance fitness ($r=-0.20$). In maximal exercise on the other hand, the relationship with weight dropped considerably and the correlation with work capacity

increased considerably. ($r=0.55$) Furthermore, Cooper (15) has obtained a correlation of 0.89 between MVO_2 established on the treadmill and the maximal distance covered in 12 minutes. Finally, Lavoie (49) has found significant correlations of 0.66 and 0.68 between MVO_2 determined by the Mitchell, Sproule and Chapman treadmill test and the 1000-meter and twelve-minute run-walks respectively.

PREDICTION OF MAXIMAL WORK CAPACITY FROM SUBMAXIMAL TESTS

The requirement for a simple work capacity test based on physiological measurements taken during submaximal stress has long been recognized. Four laboratory tests have been introduced to fulfill this need. In 1954 Astrand and Ryhming (6) introduced a nomogram from which maximal oxygen uptake could be predicted from a steady state pulse rate at a known work load. In 1958, Asmussen and Hemmingsen (1) presented a curve and a formula from which maximal oxygen uptake could be determined from measurements made during submaximal work. Issekutz (40) predicted maximal oxygen consumption from the respiratory quotient taken at submaximal levels and reported a difference of only about 5 percent between estimated and actual values. At about the same time, Workman and Armstrong (72) developed an equation to predict maximal oxygen consumption while walking on a treadmill. The equation, based on height, weight, treadmill speed and grade, readily lent itself to nomographic presentation.

THE ASTRAND-RYHMING NOMOGRAM FOR
PREDICTION OF MAXIMAL
OXYGEN CONSUMPTION

Based on the close linear relationship between pulse rate and oxygen consumption, Astrand and Ryhming (6) have constructed a nomogram in an attempt to predict aerobic capacity from stressful yet submaximal work. The nomogram involves prediction of a subject's maximal oxygen uptake from a pulse rate elicited by a constant submaximal work load. Standard adjustments are made for sex as well as the apparatus used for the exercise. (2)

RELIABILITY AND VALIDITY OF THE NOMOGRAM

The validity of the Astrand-Ryhming nomogram as a predictor of maximal oxygen consumption relies on the following assumptions:

1. A linear relationship exists between heart rate, work load and energy expenditure through submaximal work (H.R., 130-170 bpm.) as well as work resulting in heart rates as high as 195 ± 10 bpm.

2. The mechanical efficiency of stationary cycling is constant and independent of the fitness status of the individual.

3. Heart rate achieves a steady state after approximately six minutes of submaximal work.

Based on a sample of 27 male and 31 female well-

trained subjects 20-30 years of age, Astrand and Ryhming have determined the validity of the nomogram by comparing aerobic capacity calculated on the basis of the nomogram against MVO_2 determined on a treadmill or bicycle ergometer. Statistical analysis revealed a mean difference of $0.027 - 0.059 \text{ l. O}_2/\text{min.}$ (females, $0.010 - 0.051 \text{ l. O}_2/\text{min.}$) between the determined and calculated maximal oxygen intake. The difference, expressed as a standard deviation, was less than 6.7 percent for men and 9.4 percent for women. With a lower rate of work (men, 900 vs. 1200 kgm./min. , women, 600 vs. 900 kgm./min.), the standard deviation was higher.

Serious criticism challenging the validity of the nomogram has been expressed by Wyndham et al. (74) While heart rate is linearly related to oxygen intake at low work loads, the curve tends to become asymptotic at maximal work rates. Because the oxygen uptake curve reaches its asymptote more slowly than does heart rate, a straight line extrapolated to maximal heart rate will result in an underestimation of true MVO_2 .

Other studies comparing predicted and determined MVO_2 have however, generally found the nomogram to be a good predictor of MVO_2 . Glassford et al., (31) using 24 male subjects 17-23 years of age, has obtained MVO_2 values for the Astrand-Ryhming test, the Astrand bicycle ergometer test and the Taylor, Buskirk and Henschel and the Mitchell, Sproule and Chapman treadmill tests respectively. It

was found that the Astrand-Ryhming nomogram yielded maximal oxygen uptake values equivalent to those obtained on the two treadmill tests. Furthermore, the relationship between the nomogram values and any one set of values determined by the direct technique was as good as the relation between the values of any two direct measures.

A further study comparing predicted and actual MVO_2 values has been carried out by Hettinger et al. (35). Subjects included 28 American policemen 20-30 years of age. Results indicated that the mean predicted maximal oxygen uptake (2.62 l./min.) was significantly different from the measured oxygen uptake. (2.38 l./min.) ($p=0.05$). However, the correlation between the predicted and the measured maximal oxygen uptake was statistically significant.

Larsson et al. (48) have investigated, among other variables, changes in aerobic capacity as a result of training. Subjects consisted of 12 boys, one-half of whom were diabetics. Although aerobic work capacity measured directly was 0.2 l./min. higher (7.9 percent) than those values calculated from the nomogram, the differences were not significant. Furthermore, it was concluded that the nomogram was applicable to adolescents as in addition to the 20-30 year olds from which the nomogram was constructed.

PULSE RATE AND OXYGEN CONSUMPTION
RELATED TO THE AGE GROUP
BEING STUDIED

Because the nomogram is based on figures obtained

from an age group older than the sample tested in the present investigation, it is necessary to ascertain whether or not a younger group could meet prerequisites (1) and (3).

Bengtsson (9) reported that for subjects aged 5 to 40 years, heart rate increased linearly with exercise intensity. Oxygen consumption, when compared to exercise intensity, showed the same relationship.

In 1938 Robinson (54) reported a study in which 11 boys with a mean age of 14.1 years reached pulse rate means of 195 bpm. after a 5-minute run on the treadmill. In the same report, a similar study (24) is cited in which boys with ages ranging from 12-19 years reached average maximum heart rates of 195 bpm.

In 1963 Cumming and Cumming (18) reported that Winnipeg children with ages ranging from 6-16 years maintained pulse rates from 190-200 bpm. without indicating any undue discomfort. In a similar study Cumming and Dazinger (19) found only 4 of 49 subjects aged 10-11 years were unable to reach a pulse rate of 200 bpm.

THE ASSESSMENT OF CARDIORESPIRATORY FITNESS BY FIELD TESTS

As a result of the time-consuming and expensive procedure of determining MVO_2 by laboratory techniques, a number of investigators have sought to develop field tests to estimate MVO_2 from the absolute distance covered in a

certain time period. Balke (8) has examined the relationship of runs 1-30 minutes in duration and MVO_2 . MVO_2 was determined by a standardized treadmill test and compared with oxygen requirements estimated for average velocities achieved in best effort runs for the various times. Results revealed that performance in runs of 12-20 minutes, expressed as oxygen consumption per minute, matched the objectively measured aerobic capacity most closely. Runs of shorter duration resulted in a higher proportion of the performance being accomplished anaerobically and as a result, did not reflect aerobic power. Runs greater than 20 minutes duration resulted in performance inferior to that on the treadmill, averaging 9 percent below MVO_2 capacity. As a result of his investigation, Balke established a 15-minute maximum distance field test in which the total distance covered, expressed in oxygen consumption per minute, was thought to most closely approximate an individual's aerobic capacity measured objectively.

Re-evaluation by Cooper (15) of Balke's 15-minute field test to estimate MVO_2 lead to the incorporation of a 12-minute, maximal distance field test. This test correlated better with MVO_2 established on the treadmill than did similar tests with times varying from 6-20 minutes. Whatever distance is covered in twelve minutes may roughly be converted into mls. O_2 consumed/kgm. body weight/minute. These estimates however were based on United States Air Force personnel. Lavoie (49) found that when MVO_2 of male

university students was measured objectively by a standardized treadmill test and compared to those norms established by Cooper for maximal distance covered in twelve minutes, Cooper's norms resulted in an overestimate of actual MVO_2 by about 10 percent.

RELIABILITY OF FIELD TESTS

In a comparison of the 1000-meter and twelve-minute run-walk as tests of aerobic power, Lavoie (49) found reliability coefficients of .95 and .94 respectively. Similarly, Doolittle and Bigbee (25) found a reliability coefficient of .94 upon test-retest of 153 grade nine boys in the twelve-minute run-walk.

CHAPTER III

METHODS AND PROCEDURES

SUBJECTS

A sample of 80 subjects was obtained from among students participating in the required high school physical education program at Henry Wisewood Senior High School in Calgary, Alberta. A preliminary twelve-minute run-walk test was administered to each of the subjects at the initiation of the investigation. On the basis of obtained scores, expressed as the absolute distance covered in twelve minutes (to the nearest twenty-five yards), the subjects were ranked 1-80. Beginning with subject 1, subjects were divided into blocks of four. Each subject within each block was then randomly assigned to one of the four treatments. A one-way analysis of variance was applied to the data to ensure that no significant differences existed between treatment means at the initiation of the experiment.

As an added measure of cardiorespiratory endurance, the Astrand-Ryhming nomogram test was administered to each subject prior to the initiation of the jogging program.

TRAINING PROGRAM

Five times weekly for six weeks the three experimental treatments carried out a predetermined jogging program. Group I jogged $3/8$ of a mile, Group II, $3/4$ of a mile, and Group III, 1 mile. Group IV acted as a control. While the duration of jogging varied, intensity was held constant. That is, lap times were identical for each of the three experimental treatments each week. The intensity of jogging however, increased weekly over the six weeks. An exact description of the training schedule is given in Appendix C.

No attempt was made in applying restrictions on the daily life of the subjects involved. In order to determine the effects of jogging, the maintenance of each subject's normal pattern of life is required. Any intervention may elicit effects that have nothing to do with the training program, per. se.

TESTS OF CARDIORESPIRATORY ENDURANCE

At the completion of the six-week jogging program the twelve-minute run-walk was administered to each subject. The test was carried out on an indoor track. Absolute distance covered in twelve minutes (to the nearest twenty-five yards) was recorded. The Astrand-Ryhming nomogram test was also administered to each subject at the

end of six weeks of training.

THE ASTRAND-RYHMING TEST FOR PREDICTION OF MAXIMAL OXYGEN CONSUMPTION

The test was performed on a Monarch bicycle ergometer. The mechanical arrangement is so dimensioned that one complete turn of the pedals moves a point on the wheel rim six meters. The externally performed work (kilogram meters per minute) may therefore be calculated from a knowledge of work load and pedal frequency. Pedal frequency was established at 60 revolutions per minute.

Two minutes before the commencement of the test, resting heart rate was recorded. On this basis a work load was set which would elicit a pulse rate within a range of 130-170 bpm. in six minutes. The subjects pedalled at this workload until a steady state was attained (heart rate recordings at the end of the fifth and six minutes that did not differ more than ± 5 bpm.). If differences in pulse rate exceeded this value, the subject continued to exercise until this criterion was reached. All heart rate recordings were made on a Bitcher Electrocardiograph during the last 15 seconds of the fifth and sixth minutes.

CALIBRATION OF THE BICYCLE ERGOMETER

Calibration was elicited by removing the brake drum and setting the pendulum to 0. A calibrated weight

of one kilogram was added to the end of the lever and the resulting pendulum deflection read from the scale. Additional one kilogram weights were added up to a total of seven kilograms. If adjustments were required they were affected by means of an adjusting screw that altered the center of gravity of the sinus balance.

STATISTICAL TREATMENT

On the basis of the distance travelled in the twelve-minute run-walk at the initiation of the investigation, subjects were rank ordered, blocked into groups of four and randomly assigned to one of the four treatments. No significant differences were found to exist between treatments in either the twelve-minute run-walk or predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at this time.

Existence of differences in the number of laps covered in 12 minutes within each treatment over the six-week jogging program were tested for significance by a two-way analysis of variance with repeated measures of one factor (71). Differences in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ within each treatment were tested in a similar manner. Differences in the twelve-minute run-walk as well as predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ between treatments at the completion of jogging were also tested for significance by a two-way analysis of variance with repeated measures. (71) Where the analysis yielded a significant F, specific mean differences were analysed by a Scheffé test for the compar-

ison of means two at a time. (29) Interaction between treatment and initial fitness level was tested for significance by a two-way analysis of variance of gain scores. Finally, the Pearson Product-moment correlation coefficient was employed at the initiation and completion of the jogging program in determining the relationship between the Astrand-Ryhming nomogram and the twelve-minute run-walk as tests of cardiorespiratory endurance.

CHAPTER IV

RESULTS AND DISCUSSION

RESULTS

Mean and Range Values for Age, Height and Weight

Mean and range values for age, height and weight for the eighty subjects who participated in the investigation are depicted in Table I.

TABLE I

MEAN AND RANGE VALUES FOR AGE,
HEIGHT AND WEIGHT

PARAMETER	MEAN		RANGE	
	Pre-Jog.	Post-Jog.	Pre-Jog.	Post-Jog.
Age (yrs./mos.)	15-6		14-2,17-7	
Height (inches)	68.0		51.0-75.0	
Weight (pounds)	135.2	133.3	98.1-220.0	101.2-223.4

Twelve-Minute Run-Walk

A primary objective of the present investigation was to determine changes in cardiorespiratory endurance as a result of three six-week jogging programs. Changes in

the mean distance covered in twelve minutes by the four treatments after six weeks of jogging are shown in Table II.

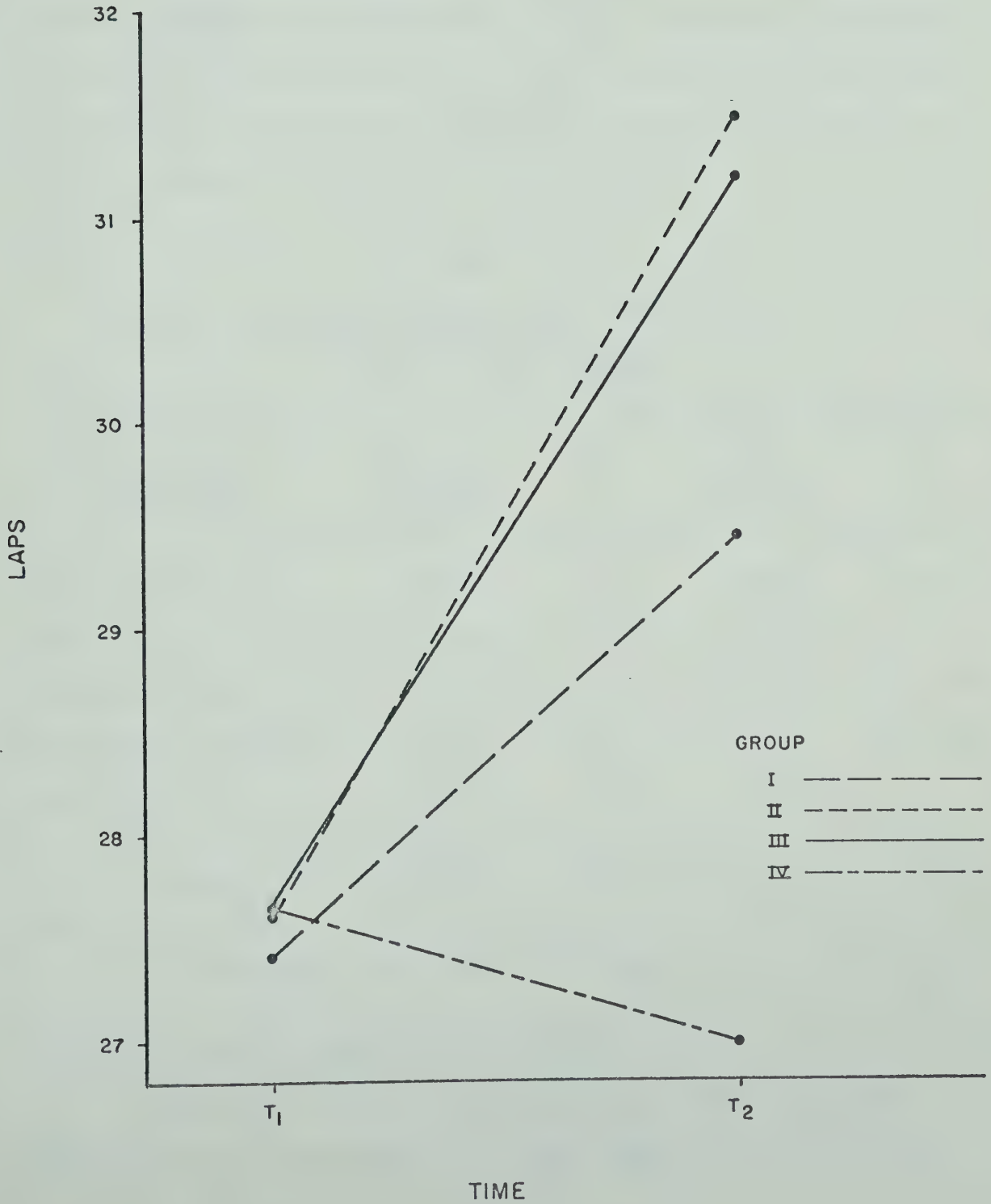
TABLE II
MEAN DISTANCE COVERED IN TWELVE MINUTES
(1 LAP = 0.05 MILES)

GROUP	PRE-JOGGING	POST-JOGGING
I	27.40	29.45
II	27.60	31.50
III	27.65	31.20
IV	27.65	27.00

Figure I graphically depicts improvement in mean treatment scores after six weeks of jogging.

FIGURE I

CHANGES IN THE MEAN DISTANCE COVERED IN
THE TWELVE-MINUTE RUN-WALK WITH
JOGGING (1 LAP=0.05 MILES)



Analysis of Variance for the Twelve-Minute Run-Walk

Existence of differences in the number of laps covered in the twelve-minute run-walk by each treatment at the completion of the jogging program were tested for significance by a two-way analysis of variance with repeated measures of one factor. (71) Table III indicates a summary of the analysis. A significant B or time effect as well as a significant interaction effect was found at the 0.01 level.

TABLE III

ANALYSIS OF VARIANCE FOR THE
TWELVE-MINUTE RUN-WALK
(1 LAP = 0.05 MILES)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
A Main Effect	128.43	3	42.81	2.19
error a	1486.81	76	19.56	
B Main Effect	195.78	1	195.78	97.77*
AB Groups x Trials	128.51	3	42.84	21.26*
error b	153.13	76	2.02	
Total	2092.81	159		

*Significant at the 0.01 level

Variation Due to Simple Main Effects

Because a significant AB interaction was noted, tests on simple main effects rather than direct tests on

main effects were required. Improvement in the number of laps covered in the twelve-minute run-walk by each treatment at the completion of six weeks of jogging was tested for significance by employing an F ratio to test the simple main effect of factor B or time effect. A summary of the analysis is shown in Table IV.

TABLE IV
VARIATION DUE TO SIMPLE
MAIN EFFECT OF FACTOR B
(1 LAP = 0.05 MILES)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
B @ A ₁	42.4	1	42.4	20.9*
B @ A ₂	152.1	1	152.1	74.2*
B @ A ₃	125.3	1	125.3	62.0*
B @ A ₄	4.4	1	4.36	2.16
MS _b x subj.w.groups	153.1	76	2.02	

*Significant at the 0.01 level

All three experimental treatments then, improved significantly in the twelve-minute run-walk over six weeks of jogging.

Differences in the number of laps covered in the twelve-minute run-walk between treatments at the completion of the jogging program were tested for significance by employing an F ratio to test the simple main effect of

factor A or treatment effect. A summary of the results was shown in Table V.

TABLE V

VARIATION DUE TO SIMPLE
MAIN EFFECT OF FACTOR A
(1 LAP = 0.05 MILES)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
MS_a at b_2	267.51	3	89.17	8.26*
$MS_{w.cell}$	1639.93	152	10.79	

*Significant at the 0.01 level

In order to determine specific mean differences, a Scheffé test for the comparison of treatment means two at a time was employed. A significant difference was found to exist between the control group and treatment II as well as the control group and treatment III. No significant differences were found to occur between any other means. A summary of the analysis is depicted in Table VI.

TABLE VI

SCHEFFÉ TEST APPLIED TO A COMPARISON OF THE
MEAN DISTANCES COVERED IN THE TWELVE-
MINUTE RUN-WALK BETWEEN K=4 TREAT-
MENT MEANS AT THE COMPLETION OF
THE JOGGING PROGRAM
(1 LAP = 0.05 MILES)

MEAN COMPARISON	F
I, II	3.89
I, III	2.84
I, IV	5.56
II, III	0.08
II, IV	18.77*
III, IV	16.35*

*Significant at the 0.01 level

Comparison of Improvement of
Upper and Lower Halves
Within Treatments

Existence of differences in improvement in the number of laps covered in the twelve-minute run-walk between the upper and lower halves of each treatment at the completion of six weeks of jogging were tested for significance by a two-way analysis of variance. The farther down a subject was in a group, the poorer his cardiorespiratory endurance at the initiation of the training regime. Consequently, it was thought that the lower half of each treatment might improve significantly more than the upper half. Table VII indicates a summary of the analysis. An

insignificant AB interaction effect was found at the 0.05 level.

TABLE VII

SUMMARY OF ANALYSIS OF VARIANCE OF IMPROVEMENT
SCORES IN THE TWELVE-MINUTE RUN-WALK
(1 LAP = 0.05 MILES)

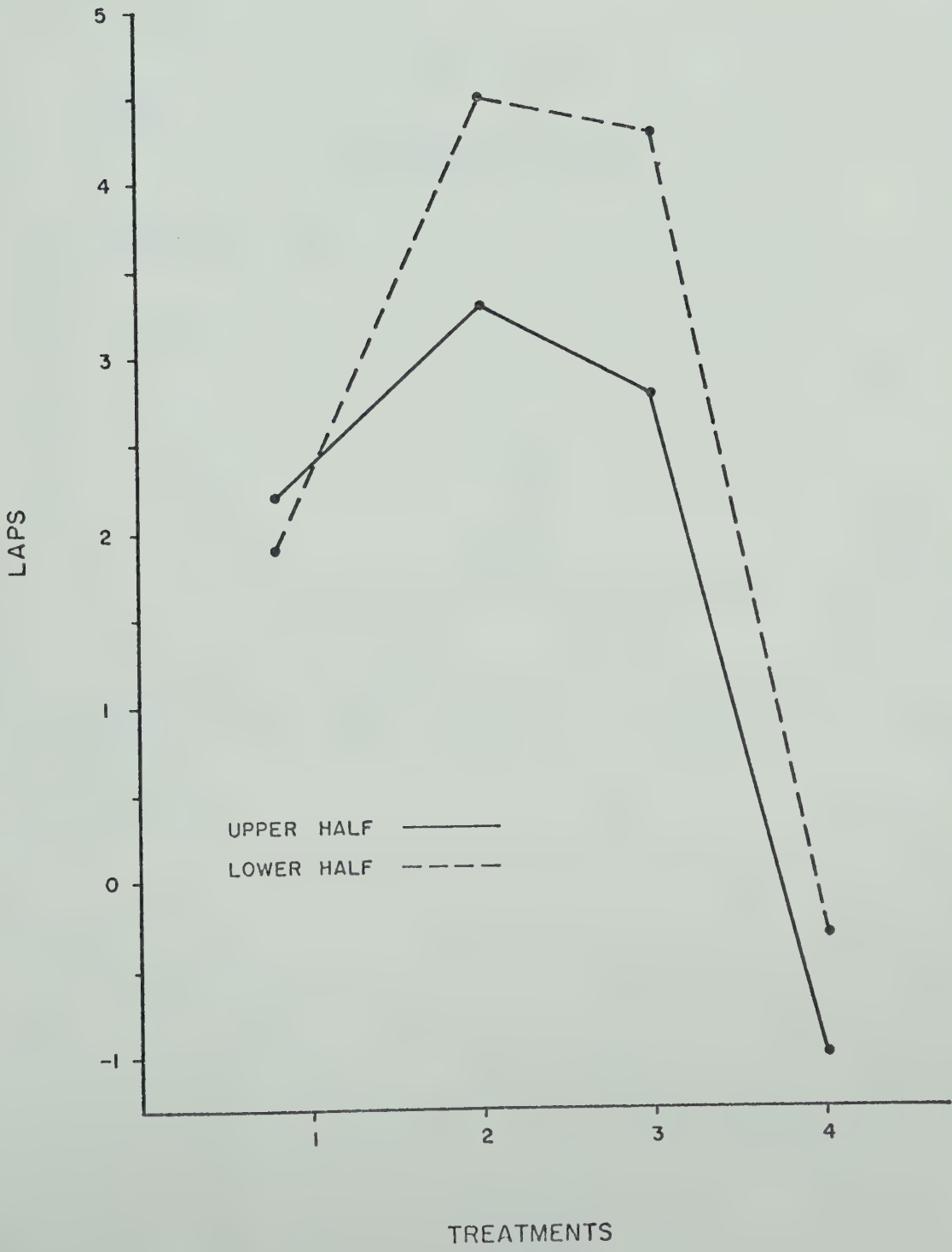
SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
A	12.01	1	12.01	3.04
B	257.14	3	85.71	21.66*
AB interaction	9.33	3	3.11	0.79
Within cell	284.9	72	3.96	
Total	563.38	79		

*Significant at the 0.01 level

Figure II graphically depicts improvement scores by the upper and lower halves of each treatment after six weeks of jogging.

FIGURE II

IMPROVEMENT IN THE MEAN DISTANCE COVERED
BY THE UPPER AND LOWER HALVES OF EACH
TREATMENT AFTER SIX WEEKS OF JOGGING
(1 LAP = 0.05 MILES)



Astrand-Ryhming Nomogram

A second aspect of the present investigation included the determination of changes in predicted MVO_2 as a result of jogging. Table VIII depicts mean predicted maximal oxygen consumption values before and after six weeks of jogging.

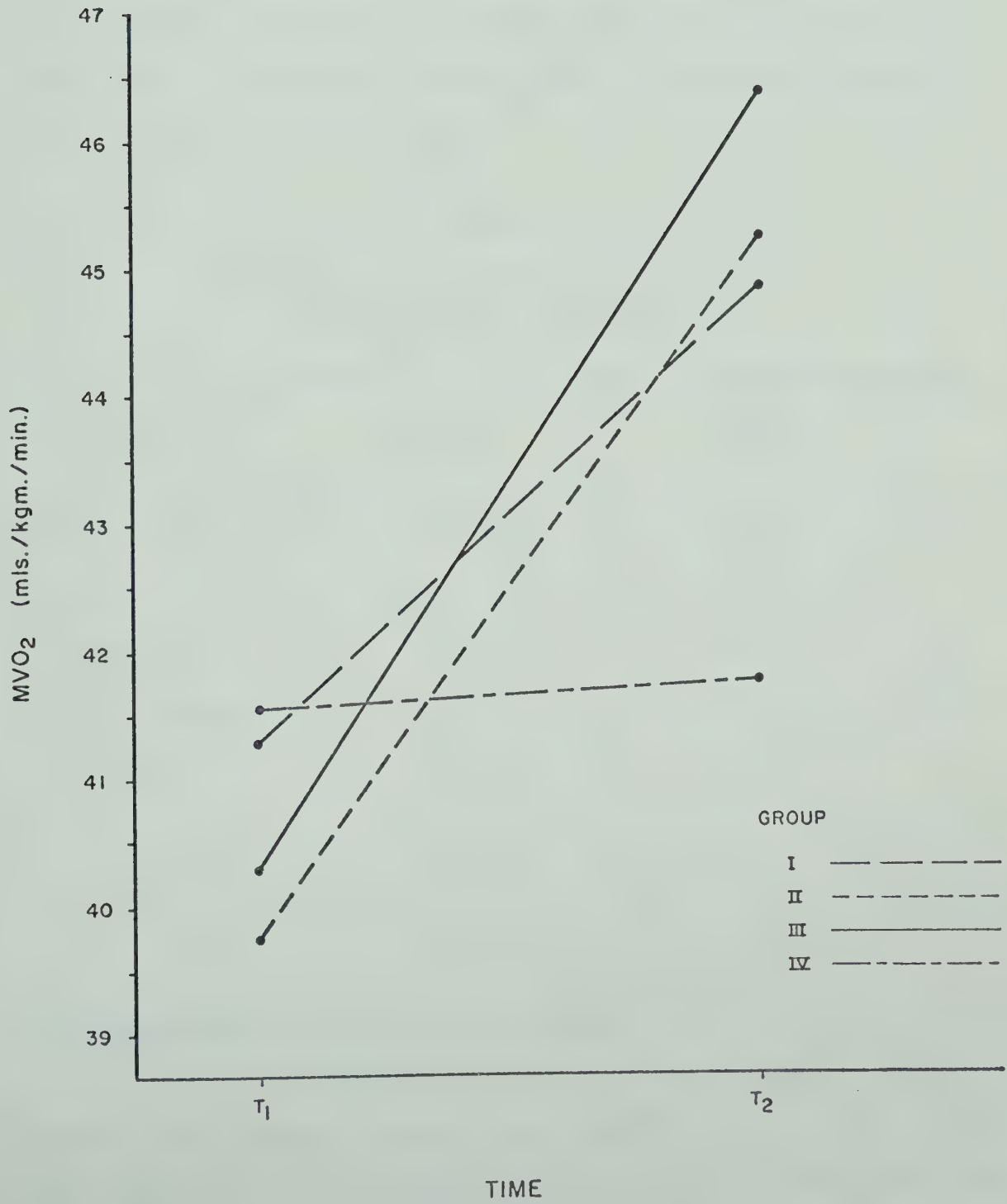
TABLE VIII
MEAN PREDICTED MAXIMAL OXYGEN
CONSUMPTION VALUES
(mls./kgm. body wt./min.)

GROUP	PRE-JOGGING	POST-JOGGING
I	41.35	44.90
II	39.75	45.30
III	40.30	46.45
IV	41.55	41.80

Figure III graphically depicts improvement in mean predicted maximal oxygen consumption values after six weeks of jogging.

FIGURE III

CHANGES IN MEAN PREDICTED MAXIMAL OXYGEN
CONSUMPTION VALUES WITH JOGGING
(mls/kgm. body wt./min.)



Analysis of Variance for the
Astrand-Ryhming Nomogram

Existence of differences in predicted MVO_2 between treatments at the completion of the jogging program were tested for significance by a two-way analysis of variance with repeated measures of one factor. (71) A summary of the results is depicted in Table IX. A significant B or time effect as well as a significant interaction effect was found at the 0.01 level.

TABLE IX

ANALYSIS OF VARIANCE FOR PREDICTED
 MAXIMAL OXYGEN CONSUMPTION
 (mls. O_2 /kgm. body wt./min.)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
A Main Effect	69.06	3	23.02	0.91
error a	10100.13	76	131.99	
B Main Effect	601.17	1	601.17	50.41*
AB interaction	211.56	3	70.52	5.91*
error b	909.31	76	11.93	
Total	21891.23	159		

*

Significant at the 0.01 level

Variation Due to Simple Main Effects

As a significant AB interaction was noted, tests on simple main effects rather than direct tests on main effects were required. Improvement in mean predicted MVO_2 /kgm./min.

by each treatment at the completion of six weeks of jogging was tested for significance by employing an F ratio to test the simple main effect of factor B or time effect. A summary of the analysis is shown in Table X.

TABLE X
VARIATION DUE TO SIMPLE MAIN
EFFECT OF FACTOR B
(predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
B @ A_1	126.7	1	126.7	10.6*
B @ A_2	308.5	1	308.5	25.8*
B @ A_3	378.9	1	378.9	31.8*
B @ A_4	0.63	1	0.63	0.05
MS_b x subj.w.groups	906.3	76	11.9	

*Significant at the 0.01 level

A significant increase in predicted $\text{MVO}_2/\text{kgm.body wt.}/\text{min.}$ was found in all three of the experimental treatments over the six-week jogging regime.

Differences in predicted $\text{MVO}_2/\text{kgm.body wt.}/\text{min.}$ between treatments at the completion of the jogging program were tested for significance by employing an F ratio to test the simple main effect of factor A or treatment effect. A summary of the analysis is given in Table XI. An insignificant F was found at the 0.05 level.

TABLE XI
 VARIATION DUE TO SIMPLE MAIN
 EFFECT OF FACTOR A
 (mls. O_2 kgm. body wt./min.)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
MS_a at b_2	237.00	3	79.0	1.10
$MS_{w.cell}$	10937.56	152	71.96	

Comparison of Improvement
of Upper and Lower Halves
Within Treatments

Existence of differences in improvement in predicted MVO_2 between the upper and lower halves of each treatment at the completion of six weeks of jogging were tested for significance by a two-way analysis of variance. Table XII indicates a summary of the analysis. An insignificant AB interaction effect was found at the 0.05 level.

TABLE XII
SUMMARY OF ANALYSIS OF VARIANCE OF
IMPROVEMENT SCORES
IN PREDICTED MVO_2
(mls./kgm. body wt./min.)

SOURCE OF VARIATION	SUM OF SQUARES	DF	MEAN SQUARE	F
A	24.20	1	24.20	0.99
B	424.55	3	141.51	5.78*
AB interaction	25.20	3	8.40	0.34
Within cell	1762.8	72	24.48	
Total	2236.75	79		

*Significant at the 0.01 level

Figure IV graphically depicts improvement scores by the upper and lower halves of each treatment after six weeks of jogging.

Correlation Coefficients

Pearson Product-moment correlation coefficients between predicted MVO_2 (mls./kgm. body wt./min.) and the distance (laps) covered in twelve minutes were calculated both before and after the jogging program. The correlations obtained are illustrated in Table XIII.

FIGURE IV

IMPROVEMENT IN MEAN PREDICTED MVO_2 BY THE
UPPER AND LOWER HALVES OF EACH TREATMENT
AFTER SIX WEEKS OF JOGGING
(mls./kgm. body wt./min.)

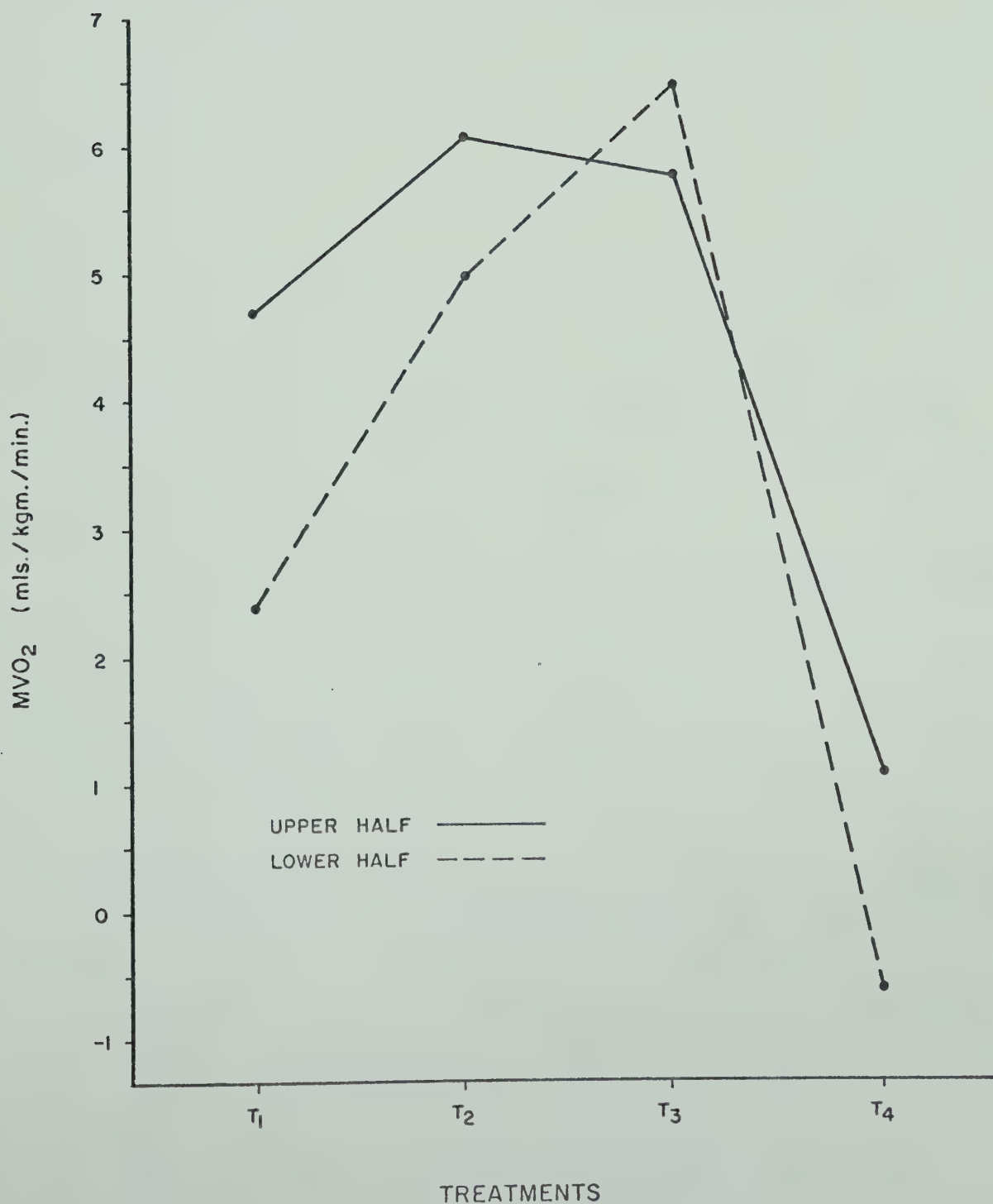


TABLE XIII
PEARSON PRODUCT-MOMENT CORRELATION
COEFFICIENTS OBTAINED BETWEEN THE
TWELVE-MINUTE RUN-WALK (LAPS)
AND PREDICTED MVO_2
(mls./kgm. body wt./min.)

	r
Pre-Jogging	0.59
Post-Jogging	0.56

DISCUSSION

Few studies have compared or validated training programs designed specifically for the development of cardiorespiratory endurance. The purpose of the present investigation was to study changes in aerobic fitness after a six-week jogging program.

Only a limited number of studies have been reported on the aerobic capacity of adolescents. From Table XIV it may be seen that the values recorded in the present study are within the range of those reported by other investigators. Because these values reflect different means of assessing MVO_2 as well as different levels of fitness, a simple comparison should be made with some reservation.

TABLE XIV

MAXIMAL OXYGEN INTAKE VALUES REPORTED FROM VARIOUS STUDIES

AGE	PRESENT STUDY			ASTRAND (1952)			RODAHL et al. (1961)		
	SEX	N	MVO ₂ (l./min.)	SEX	N	MVO ₂ (l./min.)	SEX	N	MVO ₂ (l./min.)
14				M	5	3.16	M	16	1.85
14				F	5	2.52	F	19	1.34
15				M	3	3.35	M	10	2.03
15	M	80	2.52 (pre-jog.)	F	8	2.66	F	9	1.26
15			2.87 (post-job.)						
16				M	3	3.37	M	10	2.07
16							F	5	1.22

Effects of Jogging On Aerobic Capacities

Although the principle of overload has been well established, the exact nature of the training stimulus is unknown. The concept that a threshold intensity of effort corresponding to a pulse rate of 140-150 bpm. is necessary for a cardiorespiratory training effect to occur has not been substantiated in all investigations (26) and may depend in part upon the initial fitness level of the subjects involved. On the other hand, cardiorespiratory adaptations to a training program may also be determined by the duration of stimulation. It has been hypothesized that if the intensity of exercise is sufficient to elicit a heart rate of 140-150 bpm. or more, the duration of training required to give rise to an aerobic training effect must exceed five minutes. (14, 45) However, the duration of stimulation necessary for cardiorespiratory adaptations to take place may also depend upon the individual's initial level of aerobic fitness as well as the intensity of exercise.

Mean changes in the twelve-minute run-walk and predicted maximal oxygen consumption are summarized in Table II and Figure I and Table VIII and Figure III respectively. A significant improvement in the twelve-minute run-walk as well as predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ was found in all three experimental treatments at the conclusion of the jogging program. On the other hand, no significant differences were found to exist between experimental

treatments in either the twelve-minute run-walk or predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the completion of jogging. Significant differences were found however in the mean distance covered in 12 minutes after six weeks of jogging between treatment II (3/4 mile) and treatment IV (control) and treatment III (1 mile) and treatment IV.

These findings may be attributable to a number of factors. The principal reason, in all likelihood, is that the six-week jogging period was too short. As a result, insufficient time was allowed for individuals to reach the maximal level of aerobic power characteristic of each treatment effect. Had the jogging program been extended to eight or possibly ten weeks, significant differences between treatments may have occurred.

Secondly, while a significant interaction effect was found, no significant differences in predicted MVO_2 were found between any treatments at the completion of the six-week jogging program. Increases in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ of 8.8 percent, 13.9 percent and 15.3 percent however were found in treatments I, II and III respectively. By referring to Figure III it may be seen that each of the experimental treatments exhibited an initial deficit in predicted MVO_2 when compared to the control group. While these differences were insignificant, they had to be overcome and hence contributed to the lack of significance found between treatment means. Furthermore, a substantial amount of variability in predicted MVO_2 was found to occur

within treatments. To what extent this is attributable to the use of the Astrand-Ryhming nomogram cannot be ascertained. On the other hand, it may reflect true variations in improvement in MVO_2 by individuals within the same treatment. Whatever the cause, the substantial amount of variability exhibited within each group was another factor contributing to the lack of significance found between treatment means.

Effect of Initial Fitness Levels on Improvement in Aerobic Fitness

Because subjects were assigned to treatments according to the distance covered in twelve minutes, the lower his position in a treatment, the poorer the subject's initial level of aerobic power. It had been hypothesized previously that each jogging treatment might influence the lower half of each group significantly more than the upper half. It is conceivable that a maximal cardiorespiratory fitness level or 'Endkraft' may result from each of the treatment effects. Because the lower half of each group is more distant from that maximum, a greater improvement in aerobic power might be expected. This might also help to explain the substantial variability found within treatments in improvement in predicted MVO_2 with jogging.

This however was not found to be the case. Differences in improvement in the distance covered in the twelve-minute run-walk as well as predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$

between the upper and lower halves of each treatment were not found to be significant at the 0.05 level.

This finding may be the result of one of two reasons:

It is conceivable that those subjects who initially exhibited the lowest levels of cardiorespiratory endurance possess certain physiological or morphological limitations that inhibit the rate at which they may improve in aerobic power. Limiting characteristics might include for example, heart size, lung volume, muscle mass or any other parameters involved in aerobic performance.

On the other hand, the increase in the intensity of jogging may have been sufficient and the over-all duration (six weeks) insufficient to allow any subject to reach the maximal level of aerobic fitness characteristic of each treatment effect. Consequently, those subjects who were initially superior in aerobic power improved at a rate that was maximal for that group. Those subjects who initially possessed a lesser degree of cardiorespiratory endurance improved in a similar manner. As a result, no differences in improvement in cardiorespiratory fitness between treatment levels were demonstrated. Had the jogging program been extended and increases in the intensity of jogging decreased or held constant, a significant difference in improvement may have been illustrated.

Correlation Coefficients

Significant correlations of 0.59 and 0.56 were found between predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ and the distance covered in the twelve-minute run-walk at the initiation and conclusion of the jogging regime respectively. Lavoie (49) has found similar correlations of 0.66 and 0.68 between MVO_2 determined directly by a treadmill test and the 1000-meter and twelve-minute run-walk respectively. A correlation of 0.89 on the other hand has been reported by Cooper between MVO_2 established on the treadmill and the twelve-minute run-walk. (15)

The subjects involved in Cooper's investigation included 115 United States Air Force personnel in good physical condition. The variation in age then may have been a factor which contributed to the lower correlations obtained in the present study. On the other hand, the correlations reported by Lavoie (49) were obtained from a sample in which the age range was similar to that found in Cooper's study. Furthermore, Lavoie employed a direct test for maximal oxygen uptake analysis. While undoubtedly the Astrand-Ryhming nomogram contributed to predictive error, the moderate correlations obtained in the present study were not, in all likelihood, solely related to its use.

Although the variability explained by the above two correlations is not great, it does not necessarily imply that the twelve-minute run-walk and the Astrand-

Ryhming nomogram are poor predictors of aerobic capacity. Glassford et al. (31) for example have found correlation coefficients of 0.68 and 0.65 between three direct tests of maximal oxygen consumption. Cooper's correlation appears unrealistically high and should be looked upon with some reservation.

CHAPTER V

SUMMARY AND CONCLUSIONS

SUMMARY

The purpose of the present study was to investigate changes in cardiorespiratory endurance after a six-week jogging program. A further aspect of the study included a comparison of improvement in cardiorespiratory endurance by individuals within the same treatment who exhibited varying levels of aerobic fitness at the initiation of jogging. Finally, Pearson Product-moment correlation coefficients were obtained between the distance covered in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm. body wt./min.}$ at the initiation and completion of the jogging program.

Three experimental treatments were employed. A fourth group acted as a control. Jogging took place five times weekly on an indoor track. Eighty high school students with an average age of 15-1/2 years participated in the investigation.

On the basis of the distance travelled in the twelve-minute run-walk, (nearest 25 yards) subjects were rank ordered, blocked into groups of four and randomly assigned to one of the four treatments. The Astrand-Ryhming nomogram test was also administered to each

subject before the jogging program commenced. No significant differences in the twelve-minute run-walk or predicted $\text{MVO}_2/\text{kgm. body wt./min.}$ were found to exist between treatment means at the initiation of the investigation.

The three experimental groups then began the jogging program. Treatment I jogged $3/8$ of a mile, treatment II, $3/4$ of a mile, and treatment III, one mile. While the duration of jogging varied, intensity was held constant. That is, lap times were identical for each of the three groups each week. The intensity increased weekly during the six weeks of jogging.

Changes in aerobic power at the completion of the jogging program were determined by again employing the twelve-minute run-walk and the Astrand-Ryhming nomogram test.

Existence of differences in the twelve-minute run-walk as well as predicted $\text{MVO}_2/\text{kgm./min.}$ within treatments over the six-week jogging program were tested for significance by a two-way analysis of variance with repeated measures of one factor. Existence of differences in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm./min.}$ between treatments at the completion of jogging were tested in a similar manner. Differences in improvement in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm./min.}$ between the upper and lower halves of each treatment were tested for significance by a two-way analysis of variance.

Where the analysis yielded a significant F, specific mean differences were determined by a Scheffé test for the comparison of means two at a time. Finally, Pearson Product-moment correlation coefficients were obtained between the twelve-minute run-walk and the Astrand-Ryhming nomogram at the initiation and completion of the jogging program.

Results indicated that all three experimental groups exhibited a significant increase in both the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ over the six-week jogging program. No significant change in either variable was found to occur in the control group. Significant differences in the twelve-minute run-walk were found between treatment II (3/4 mile) and treatment IV (control) and treatment III (1 mile) and treatment IV at the completion of jogging. On the other hand, no significant differences in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ were found between treatments at the conclusion of jogging. Furthermore, no significant differences in improvement in aerobic power (distance covered in 12 minutes, predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$) were found when the upper and lower halves of each treatment were compared. Finally, correlations of 0.59 and 0.56 were found between the distance covered in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the initiation and completion of the jogging program respectively.

CONCLUSION

Within the limitations of the study it was concluded that:

1. A significant improvement in the twelve-minute run-walk occurred as a result of jogging $3/8$ of a mile, five times per week for six weeks at the suggested intensities. This improvement was not however, significantly different from the control group. Jogging $3/4$ of a mile or 1 mile at the same intensity and frequency did not result in a significant improvement in the twelve-minute run-walk over that obtained by jogging $3/8$ of a mile. On the other hand, the improvement in the twelve-minute run-walk resulting from jogging $3/4$ of a mile and 1 mile were found to be significantly different from the control group.

2. Jogging $3/8$ of a mile, five times per week for six weeks resulted in a significant increase in predicted $MVO_2/\text{kgm.}/\text{min.}$ (8.8 percent). Jogging $3/4$ of a mile and 1 mile at the same intensity and frequency also resulted in significant increases in predicted $MVO_2/\text{kgm.}/\text{min.}$ (13.9 percent, 15.3 percent respectively). No significant differences were found however between the three experimental treatments or between the experimental treatments and the control at the completion of the jogging program.

3. Mean improvement in cardiorespiratory fitness (twelve-minute run-walk, predicted $MVO_2/\text{kgm.}/\text{min.}$) over

six weeks of jogging was not found to be significantly different when the upper and lower halves of each treatment were compared.

4. Significant correlations of 0.59 and 0.56 were found to exist between the distance covered in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ at the initiation and completion of the six-week jogging program respectively.

RECOMMENDATIONS

1. It was found within the present study that a six-week jogging program was insufficient to bring about significant differences in treatment effects. Consequently, future programs comparing improvements in cardiorespiratory endurance should be extended to eight or possibly ten weeks.

2. A substantial amount of within-group variability was noted in the analysis of improvement in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ To what extent this variance is attributable to the Astrand-Ryhming nomogram is unknown. No significant differences in predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ were found when the upper and lower halves of each treatment were compared. The variability therefore cannot be attributable to high gains in MVO_2 by those subjects who initially exhibited low levels of aerobic fitness and smaller gains by those subjects who initially exhibited higher levels of cardiorespiratory fitness. Future

studies then might compare physiological and possibly psychological parameters of high gainers in MVO_2 with low gainers.

3. The optimal amount of jogging required to produce a significant improvement in cardiorespiratory endurance is, in all likelihood, dependent upon the individual's sex, age and present level of aerobic fitness. It is quite conceivable that a point exists beyond which further effort no longer is effective in increasing the intensity of the training stimulus. Therefore it may be possible to delimit optimal intensities and durations of jogging for individuals at various levels of cardiorespiratory endurance. A validated program somewhat like that established by Cooper could be set up. However, optimal amounts of jogging would vary not only according to the individual's sex, but age as well.

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APPENDIX A

RAW DATA

INFORMATION PERTAINING TO INDIVIDUAL
SUBJECT'S PHYSICAL CHARACTERISTICS

GROUP I

SUBJECT	AGE	HEIGHT	PRE-JOG.	POST-JOG.	SMOKE	
	(Yrs.-Mos.)	(in.)	WEIGHT (Kg)	WEIGHT (Kg)	Yes	No
1.	14-10	68	65.9	65.9		x
2.	16- 3	69	56.4	55.4	x	
3.	15-11	69	70.9	71.8		x
4.	15- 7	69	56.8	57.3		x
5.	15- 9	73	60.5	61.4	x	
6.	15- 7	73	75.9	75.5		x
7.	16- 1	68	69.6	68.2		x
8.	15- 2	65	52.3	52.7		x
9.	15-11	68	61.8	60.9	x	
10.	15- 8	70	66.4	64.6		x
11.	16- 2	69	60.9	59.1	x	
12.	16- 3	72	62.7	61.4		x
13.	15- 7	66	61.8	62.7		x
14.	15- 5	70	75.5	74.6		x
15.	15-10	68	61.4	61.8		x
16.	16- 0	68	61.8	61.8		x
17.	15- 7	70	73.6	74.6		x
18.	14- 7	71	69.1	68.6		x
19.	15- 8	63	52.3	53.6		x
20.	15- 7	69	67.3	67.7	x	

INFORMATION PERTAINING TO INDIVIDUAL
SUBJECT'S PHYSICAL CONDITION

GROUP II

SUBJECT	AGE	HEIGHT	PRE-JOG. WEIGHT	POST-JOG. WEIGHT	SMOKE	
	(Yrs.-Mos.)	(in.)	(Kg)	(Kg)	Yes	No
1.	15- 8	72	66.4	66.8		x
2.	15-11	71	74.1	73.2		x
3.	15-11	68	60.5	60.5		x
4.	14-10	68	67.3	66.4		x
5.	15- 5	69	64.1	64.6		x
6.	14-10	67	60.0	59.6		x
7.	14- 4	68	57.3	57.7		x
8.	15- 1	64	44.6	46.4		x
9.	16- 3	68	54.6	53.2		x
10.	15- 7	69	64.1	63.2		x
11.	15- 8	71	66.4	65.0		x
12.	16- 0	72	66.4	66.8		x
13.	15- 6	65	51.8	50.5	x	
14.	17- 7	69	52.3	51.4	x	
15.	15- 6	68	61.8	62.3		x
16.	16- 3	69	104.6	103.6		x
17.	14-11	68	64.6	64.1	x	
18.	15- 5	62	59.1	59.6		x
19.	16- 2	72	68.2	68.2		x
20.	16- 6	70	62.7	60.5		x

INFORMATION PERTAINING TO INDIVIDUAL
SUBJECT'S PHYSICAL CONDITION

GROUP III

SUBJECT	AGE	HEIGHT	PRE-JOG.	POST-JOG.	SMOKE	
	(Yrs.-Mos.)	(in.)	WEIGHT (Kg)	WEIGHT (Kg)	Yes	No
1.	14- 9	66	51.4	52.3		x
2.	16- 4	66	55.5	55.5		x
3.	15-11	70	65.0	65.5	x	
4.	15-10	67	60.0	60.9	x	
5.	15- 8	68	61.4	60.9		x
6.	15- 9	69	63.6	64.5		x
7.	14- 2	71	61.8	61.8		x
8.	15- 0	70	61.4	61.4		x
9.	15- 5	71	68.2	66.4		x
10.	15- 6	66	62.7	61.8		x
11.	16-11	70	70.9	69.6		x
12.	15- 7	70	68.2	68.2		x
13.	15- 6	67	59.1	58.6		x
14.	15-11	69	57.7	57.7		x
15.	15-11	68	63.6	64.1	x	
16.	15- 6	70	79.6	78.6		x
17.	15- 5	69	52.3	52.3		x
18.	14- 8	69	81.8	81.8		x
19.	15- 2	70	71.7	71.7	x	
20.	15- 8	68	66.8	66.4		x

INFORMATION PERTAINING TO INDIVIDUAL
SUBJECT'S PHYSICAL CONDITION

GROUP IV

SUBJECT	AGE (Yrs.-Mos.)	HEIGHT (in.)	PRE-JOG. WEIGHT (Kg)	POST-JOG. WEIGHT (Kg)	SMOKE	
					Yes	No
1.	15- 6	70	56.4	58.2		x
2.	15- 7	57	39.6	40.9		x
3.	15-11	65	50.0	50.0		x
4.	15- 8	66	54.6	56.8		x
5.	16- 2	67	68.2	66.4		x
6.	15- 6	68	63.6	62.3	x	
7.	16- 2	68	59.1	59.1		x
8.	15- 5	66	50.0	50.0		x
9.	15- 0	66	52.3	53.2		x
10.	14-10	69	100.0	101.8	x	
11.	14- 8	68	70.5	70.5		x
12.	16- 0	58	57.7	58.6		x
13.	15- 2	75	77.3	78.6		x
14.	16- 0	69	77.3	76.4	x	
15.	16- 0	69	50.0	50.9		x
16.	15- 9	68	63.6	63.6	x	
17.	15- 6	51	41.8	42.3		x
18.	15- 9	66	54.6	55.0		x
19.	15-10	65	52.3	53.2		x
20.	15- 9	67	56.8	58.6	x	

DISTANCE TRAVELLED IN THE
TWELVE-MINUTE RUN-WALK
(1 Lap = 0.05 Miles)

GROUP I

SUBJECT	PRE-JOGGING	POST-JOGGING
1.	32	32
2.	32	36
3.	31	32
4.	31	34
5.	30	30
6.	30	33
7.	29	33
8.	28	30
9.	28	30
10.	28	31
11.	27	28
12.	27	29
13.	27	26
14.	26	27
15.	26	26
16.	25	28
17.	24	26
18.	23	27
19.	22	26
20.	22	25

DISTANCE TRAVELLED IN THE
TWELVE-MINUTE RUN-WALK
(1 Lap = 0.05 Miles)

GROUP II

SUBJECT	PRE-JOGGING	POST-JOGGING
1.	32	34
2.	32	33
3.	31	32
4.	30	36
5.	30	35
6.	29	33
7.	29	33
8.	29	32
9.	29	34
10.	28	30
11.	28	34
12.	28	34
13.	27	34
14.	27	30
15.	26	29
16.	25	28
17.	25	29
18.	24	31
19.	23	27
20.	20	22

DISTANCE TRAVELLED IN THE
TWELVE-MINUTE RUN-WALK
(1 Lap = 0.05 Miles)

GROUP III

SUBJECT	PRE-JOGGING	POST-JOGGING
1.	32	33
2.	32	36
3.	31	34
4.	31	30
5.	31	34
6.	30	33
7.	30	35
8.	29	32
9.	29	33
10.	28	31
11.	28	31
12.	28	33
13.	27	32
14.	27	28
15.	26	27
16.	26	31
17.	25	31
18.	23	29
19.	22	23
20.	18	28

DISTANCE TRAVELLED IN THE
TWELVE-MINUTE RUN-WALK
(1 Lap = 0.05 Miles)

GROUP IV

SUBJECT	PRE-JOGGING	POST JOGGING
1.	31	31
2.	31	32
3.	31	30
4.	30	25
5.	30	32
6.	29	28
7.	29	25
8.	29	30
9.	29	27
10.	29	28
11.	28	28
12.	28	28
13.	28	31
14.	28	26
15.	27	27
16.	26	21
17.	26	27
18.	24	24
19.	21	21
20.	19	19

INDIVIDUAL RESPONSES TO THE ASTRAND-RYHMING NOMOGRAM BEFORE JOGGING

GROUP I

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ kgm./min. (mls.)
1.	2.0	86	136	136	136	3.25	49
2.	2.0	70	136	136	136	3.25	57
3.	2.0	85	142	144	143	2.90	40
4.	2.0	94	161	164	163	2.24	39
5.	2.0	89	152	152	152	2.58	42
6.	2.0	87	134	134	134	3.35	44
7.	2.0	76	136	137	137	3.20	46
8.	2.0	80	133	133	133	2.90	55
9.	2.0	79	156	156	156	2.42	39
10.	2.0	62	137	139	138	3.15	47
11.	2.0	85	150	152	151	2.62	43
12.	2.0	98	148	150	149	2.68	43
13.	1.5	93	152	153	153	2.13	34

GROUP I (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ kgm./min. (mls.)
14.	2.0	87	168	167	168	2.00	27
15.	2.0	79	160	163	162	2.24	37
16.	2.0	83	140	140	140	3.05	49
17.	1.5	95	150	150	150	2.23	30
18.	2.0	77	156	157	157	2.38	35
19.	1.5	91	170	171	171	1.68	32
20.	2.0	82	149	151	150	2.65	39

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM BEFORE JOGGING

GROUP II

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min (mls.)
1.	2.0	91	151	152	152	2.61	39
2.	2.0	71	135	135	135	3.30	45
3.	2.0	83	135	135	135	3.30	55
4.	2.0	70	143	144	144	2.88	43
5.	2.0	81	153	151	152	2.58	40
6.	2.0	92	159	161	160	2.32	39
7.	2.0	85	155	156	156	2.42	40
8.	1.5	91	161	160	161	1.91	43
9.	1.5	93	169	170	170	1.68	31
10.	2.0	77	137	136	137	3.20	50
11.	2.0	78	153	156	155	2.48	37
12.	2.0	74	142	143	143	2.90	44
13.	2.0	65	154	156	155	2.48	48

GROUP II (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.0	71	157	158	158	2.38	45
15.	2.0	77	152	152	152	2.58	42
16.	1.0	93	157	159	158	1.58	15
17.	2.0	78	160	160	160	2.32	36
18.	1.5	95	159	159	159	1.97	33
19.	2.0	72	160	160	160	2.32	34
20.	2.0	86	163	160	162	2.24	36

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM BEFORE JOGGING

GROUP III

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.0	82	164	164	164	2.18	42
2.	1.0	97	153	153	153	1.70	25
3.	2.0	81	159	161	160	2.32	42
4.	2.0	56	134	134	134	3.35	52
5.	2.0	79	143	143	143	2.90	48
6.	2.0	80	149	149	149	2.68	44
7.	2.0	72	141	141	141	3.00	47
8.	2.0	84	154	156	155	2.48	40
9.	2.0	80	148	148	148	2.70	44
10.	2.0	76	143	145	144	2.88	42
11.	2.0	84	158	161	160	2.32	37
12.	2.0	87	153	155	154	2.50	35
13.	2.0	56	141	141	141	3.00	44

GROUP III (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.0	72	155	155	155	2.48	42
15.	1.5	90	136	138	137	2.72	47
16.	1.5	93	155	155	155	2.08	33
17.	1.5	87	141	141	141	2.55	32
18.	2.0	77	145	148	147	2.76	51
19.	1.5	94	155	155	155	2.08	25
20.	2.0	83	155	158	157	2.38	34

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM BEFORE JOGGING

GROUP IV

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.0	73	146	148	147	2.76	49
2.	1.5	93	166	164	165	1.80	46
3.	2.0	84	168	170	1q9	2.07	41
4.	2.0	79	162	164	163	2.24	41
5.	2.0	83	134	132	133	3.40	50
6.	2.0	80	146	148	147	2.76	43
7.	2.0	73	163	163	163	2.24	38
8.	1.5	94	167	167	167	1.77	35
9.	2.0	75	146	148	147	2.76	53
10.	1.0	98	136	136	136	2.25	23
11.	1.5	88	146	145	146	2.74	39
12.	1.5	79	132	130	131	3.00	52
13.	2.0	73	165	167	166	2.15	29

GROUP IV (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.0	70	140	138	139	3.10	40
15.	2.0	63	167	167	167	2.10	42
16.	2.0	85	167	167	167	2.10	33
17.	1.5	86	153	153	153	2.13	51
18.	2.0	62	166	164	165	2.16	39
19.	2.0	73	162	164	163	2.24	43
20.	2.0	81	154	156	155	2.48	44

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM AFTER JOGGING

GROUP I

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.0	83	134	134	134	3.35	50
2.	2.5	77	138	138	138	3.63	65
3.	2.5	69	136	138	137	3.68	51
4.	2.0	90	140	140	140	3.05	53
5.	2.0	76	140	140	140	3.05	49
6.	2.5	66	144	148	146	3.24	42
7.	2.5	73	144	144	144	3.32	48
8.	2.5	66	144	144	144	3.32	62
9.	2.0	87	156	158	157	2.38	39
10.	2.0	60	134	133	134	3.35	46
11.	2.0	64	159	159	159	2.28	39
12.	2.5	73	156	153	155	2.77	46
13.	2.5	81	170	170	170	2.38	35

GROUP I (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.5	77	168	171	170	2.38	30
15.	2.5	72	167	167	167	2.48	40
16.	2.5	72	144	144	144	3.32	54
17.	1.5	91	155	155	155	2.10	28
18.	2.0	74	157	156	157	2.38	36
19.	2.0	83	170	170	170	2.20	41
20.	2.0	72	135	136	136	3.25	48

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM AFTER JOGGING

GROUP II

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.5	74	163	163	163	2.60	39
2.	2.5	83	145	144	145	3.28	45
3.	2.5	84	146	146	146	3.23	53
4.	2.5	77	148	151	150	3.05	46
5.	2.5	84	154	154	154	2.90	45
6.	2.5	71	150	150	150	3.05	51
7.	2.5	86	138	138	138	3.63	63
8.	2.0	91	163	163	163	2.22	48
9.	2.5	87	170	170	170	2.38	43
10.	2.5	72	145	145	145	3.28	52
11.	2.5	78	164	167	166	2.50	38
12.	2.5	84	153	152	153	2.94	44
13.	2.0	72	146	146	146	2.78	55

GROUP II (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED (MVO ₂ (l./min.))	MVO ₂ /kgm./min. (mls.)	PREDICTED
14.	2.0	78	143	145	144	2.85	55	
15.	2.0	95	151	150	151	2.63	42	
16.	2.0	86	162	164	163	2.22	21	
17.	2.5	73	162	164	163	2.60	41	
18.	2.0	82	160	161	161	2.28	38	
19.	2.5	66	157	160	159	2.74	40	
20.	2.5	75	156	156	156	2.80	46	

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM AFTER JOGGING

GROUP III

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED MVO ₂ (l./min.)	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.0	77	150	153	152	2.60	50
2.	2.5	73	164	164	164	2.57	46
3.	2.5	60	141	140	141	3.46	53
4.	2.0	66	130	132	131	3.53	56
5.	2.5	60	141	143	142	3.41	56
6.	2.5	71	145	145	145	3.28	51
7.	2.5	84	143	145	144	3.32	54
8.	2.5	75	164	161	163	2.60	43
9.	2.5	72	148	150	149	3.10	47
10.	2.5	72	170	170	170	2.38	38
11.	2.0	84	136	136	136	3.25	47
12.	2.5	68	140	142	141	3.46	51
13.	2.5	80	161	161	161	2.67	46

GROUP III (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED MVO ₂ (l./min.)	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.5	73	162	165	164	2.57	45
15.	2.0	82	136	138	137	3.20	50
16.	2.5	72	161	161	161	2.67	34
17.	2.0	74	134	137	136	3.25	62
18.	2.0	84	161	161	161	2.28	28
19.	2.5	71	161	167	167	2.47	34
20.	2.5	67	170	170	170	2.28	36

INDIVIDUAL RESPONSE TO THE ASTRAND-RYHMING NOMOGRAM AFTER JOGGING

GROUP IV

SUBJ.	RESISTANCE (Kgm)	RHR	H.R.after 5 Min.	H.R.after 6 Min.	\bar{X} H.R.	PREDICTED MVO ₂ (l./min.)	PREDICTED MVO ₂ /kgm./min. (mls.)
1.	2.0	66	138	137	138	3.15	54
2.	1.5	84	158	161	160	1.95	48
3.	2.0	73	164	164	164	2.18	44
4.	2.0	72	161	161	161	2.28	40
5.	2.0	64	128	131	130	3.55	53
6.	2.0	81	155	155	155	2.46	40
7.	2.0	66	157	159	158	2.35	40
8.	2.0	86	170	170	170	2.20	44
9.	2.0	72	147	147	147	2.74	52
10.	1.0	93	136	134	135	2.28	22
11.	1.5	82	141	144	143	2.90	41
12.	2.0	72	138	138	138	3.15	54
13.	2.0	86	158	161	160	2.31	28

GROUP IV (continued)

SUBJ.	RESISTANCE (Kgm)	RHR	H.R. after 5 Min.	H.R. after 6 Min.	\bar{X} H.R.	PREDICTED MVO ₂ (l./min.)	PREDICTED MVO ₂ /kgm./min. (mls.)
14.	2.0	74	141	141	141	3.00	39
15.	1.5	90	164	164	164	1.83	36
16.	2.0	76	170	170	170	2.20	31
17.	1.5	79	148	148	148	2.74	54
18.	2.0	71	163	165	164	2.18	39
19.	2.0	69	163	164	164	2.18	41
20.	2.0	74	158	158	158	2.35	40

APPENDIX B
STATISTICAL TREATMENT

STATISTICAL TREATMENT

Analysis of Variance

A two-way analysis of variance with repeated measures of one factor was employed to determine significant differences in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ as a result of the jogging program. The analysis was obtained by the use of the following program:

Program: ANOVA 23

Language: Fortran IV

Differences in improvement in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ between treatment levels were tested for significance by a two-way analysis of variance. The analysis was obtained by the use of the following program:

Program: ANOVA 25

Language: Fortran IV

Correlation Coefficients

Pearson Product-moment correlation coefficients between the distance travelled in the twelve-minute run-walk and predicted $\text{MVO}_2/\text{kgm.}/\text{min.}$ were determined through the use of the following program:

Program: DEST ϕ 1

Language: Fortran IV

APPENDIX C
JOGGING SCHEDULE

TRAINING SCHEDULE

WEEK	GROUP I		GROUP II		GROUP III		GROUP IV	
	DISTANCE	TIME	DISTANCE	TIME	DISTANCE	TIME	DISTANCE	TIME
1	3/8 mile	3:45	3/4 mile	7:30	1 mile	10:00		
2	3/8 mile	3:20	3/4 mile	6:45	1 mile	9:00		
3	3/8 mile	3:00	3/4 mile	6:00	1 mile	8:00		
4	3/8 mile	2:50	3/4 mile	5:40	1 mile	7:30		
5	3/8 mile	2:40	3/4 mile	5:15	1 mile	7:00		
6	3/8 mile	2:30	3/4 mile	4:50	1 mile	6:30		

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